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ABSTRACT

This study examines the methodologies and costs of establishing educational delivery systems using satellites currently in orbit or planned. It identifies two operational system scenarios and their predicted costs. One system, the Canadian Universities Satellite System (CUSS), is hypothesized to provide the means of transmitting audio and video courses from any of about ten universities to about twenty locations. The originating stations will be classrooms equipped with monochrome cameras, microphones, and a loud speaker system for reception from remote locations. Receiving stations will be equipped with TV monitor microphones, and a loud speaker. The second system, the Provincial Educational Telephone System (PETS), is hypothesized as a network of 197 locations. Ten locations would be equipped with two audio channels to permit two courses to be delivered simultaneously. All locations would be capable of receiving four channels--three for courses and one for notes or library references. Headphones would allow mixed courses to be held in one room. Both CUSS and PETS would have a Centralized Network Control Center for ensuring that simultaneous courses from several locations are transmitted at designated frequencies, and courses and corresponding return channel frequencies are selected appropriately at each receiving station. The estimated annual cost for CUSS is $3,500,000, and for PET is $11,000 per location. All major components of cost to install and operate such systems are considered. (DAG)

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THE IMPLICATIONS OF THE EDUCATIONAL EXPERIMENTS CONDUCTED ON THE COMMUNICATIONS TECHNOLOGY SATELLITE

John S. Daniel - Principal researcher

THE USE OF SATELLITE DELIVERY SYSTEMS IN EDUCATION IN CANADA: THE COSTING OF TWO NETWORKS AND A PRELIMINARY NEEDS SURVEY

VOLUME 1

THE COSTING OF TWO NETWORKS

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John S. Daniel

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

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EXECUTIVE SUMMARY

Introduction

The application of audio visual technology in education has been somewhat slow to develop in Canada. The recent and existing experiments on the Hermes satellite have demonstrated the potential of an advanced communications system as a means of extending education by audio and visual means to widely separated locations. Hermes itself has focussed attention on the tele education delivery systems and provided the opportunity for many educational institutions to experiment with and gain understanding of both the delivery methods and the tele-teaching process. It has also presented the opportunity for researchers from widely separated institutions to meet occasionally and pool their knowledge and their problems.

It is felt that this research is now sufficiently advanced to consider the possible deployment of satellite delivery systems to extend educational opportunities on both a national and regional basis.

Thus two networks have been hypothesized and costed out to provide greater understanding to interested potential users to assist in planning of operational delivery networks.

Both of these networks postulate the use of existing or currently planned satellite systems owned and operated by Telesat Canada.

Satellite System Development in Canada

Unlike audio visual technology, satellite systems technology has developed rapidly in Canada and promises to play an increasingly important role in our national communications network - and for that matter in our international communication links to other areas of the world.

Currently Canada has three commercially operating communications satellites in orbit providing national telecommunications services; a fourth is due for launch in late 1978 and three more are due to be purchased this year.

Each of the in orbit satellites (Anik I, II, & III) has twelve channels each capable of supporting one or two television channels or several hundred voice channels. The new satellites will have up to 16 similar channels working on a new frequency band. Thus it is planned to set up a new satellite communications system by 1980. This system will be integrated into the national telecommunications network. It is anticipated that we will, therefore, have in Canada a significant oversupply situation by 1980. Such an oversupply might

create opportunities for the establishing of new services which may be advantageous to a larger cross-section of Canadians. One of these new services might be tele-education.

It is important to note that satellite systems require a significant investment and that access to them can only be achieved through the system owners and the telephone operating companies. These companies expect a return on their investment. It is therefore essential that any plan to use satellite technology recognises the need for return on investment by the telecommunications system operators.

It must also be recognised that the operating companies - like most healthy businesses - seek to optimise their return and therefore do not automatically offer users the most cost effective service. It is up to the user to define and specify clearly his requirements.

Canadian University Satellite System (CUSS)

The first system hypothesized is the CUSS Network which provides the means of originating video and audio "programs" from any one of ten universities of Canada for delivery to about twenty receiving locations plus the other nine universities. Audio return facilities are included in all locations to permit an interactive learning environment.

The system would deploy earth stations in each campus connected to a classroom equipped with the appropriate audio/visual terminal equipment.

The system has great flexibility for addition of extra channels (programs); the ability to forward course notes, library references; to deliver other audio or visual material in off-air times; to act as the focus of a provincial tele-educational system, etc.

It is estimated that the annual cost to set up a full system of thirty locations and lease the telecommunication segment is of the order of $3,500,000 excluding the cost of the audio visual equipment which is a function of choice/need of specific universities. This could mean an average provincial cost of about $350,000 for the educational delivery system.

Provincial Educational Telephone System (PETS)

The PETS Network is envisaged as a regional or provincial system using only interactive audio. A realistic model was chosen (Quebec) and a network serving 200 locations was hypothesized. This model is possibly similar in scale to that deployed in Wisconsin (population about five million) which has an external student population of 30,000 using a telephone based network.

The annual cost per location of this model is estimated to be just over $11,000 - most of it being the lease of the satellite ground station.

Conclusions

This study essentially examines methodologies and costs of putting in place educational delivery systems using satellites currently in orbit or planned. It identifies operational system scenarios and their predicted costs.

In undertaking this study the participants have not underestimated the difficulty of instituting such networks using an operating system which is not set up to address user problems - but only technical delivery problems.

If a user network is ever set up it will likely be through the efforts of the user - the educational communities and institutions in Canada - not the operating companies who have little incentive in Canada to devise and offer new user services. Thus the user will have to identify his own requirements, design his own system and stimulate the operating companies into responding to his needs.

It is believed that this study addresses most of the problems

inherent in setting up satellite based delivery system.

It is hoped that it assists the user community to better understand the possibility and in turn assist in the identification of the real need.

1. PURPOSE AND BACKGROUND OF STUDY

1.1 Communications in Education

The role of communication and audio-visual technology in education has always been a matter of high expectations, great controversy, and often disappointing results. Even the introduction of the printing press into academe is said to have been vigorously opposed by many. That particular technology has become very well accepted of course, but reliance on the chalk-board certainly continues. In all, education is primarily based on technologies of very long standing.

Yet high expectations for new technologies have continued. Thomas Edison, for example, saw his invention, the moving picture as having its greatest use in education. More recently television has been hailed as a panacea for the problems of education, although those hopes too have not materialized despite the expenditure of considerable funds.

Notwithstanding disappointed expectations, the use of media in education continues to grow year by year. With the developing emphasis on continuing education, instructional media have recently attracted attention as the technological basis for outreach education. Some systems, such as Chicago's "TV College", have been operational since the late 1950's; others

are more recent innovations. Again there have been failures but there have also been successes. The two systems costed in this study are derived from two of the successes: the University of Wisconsin telephone based extension education program, and the instructional television system at Stanford University in California. In both cases communications technology is utilized so that travel to the campus where the course is being given is not essential to "attending" the course. Education is delivered to the student where he is, and he is able to interact with the lecturer and the other students through the communication system.

While less satisfactory in many ways than being in the classroom with the teacher, such systems do work. If the alternative is not being able to attend the course, such "teleteaching" can be enthusiastically received by students.

Canada is a federation in which geographic and cultural circumstances have made communications more than ordinarily important. Strangely enough, however, we have not been notably active in the application of communications to education. On the one hand, Canada is a world leader in communications technology; on the other hand, the use of this technology in education is virtually non existant.

This study looks at the cost implications of using our newest communications systems - communications satellites - in two educational applications.

1.2 Review of Satellite System Utilisation in Canada

The launching of Anik 1 in November 1972 heralded the start of a new Canadian communications system. The prospect of new and improved service to areas previously suffering poor or no service was eagerly awaited by users.

In the remarkably short space of time between the enabling legislation defining the incorporation of Telesat Canada (Sept. 69) and early 1973 a new national telecommunications system had been established delivering television, radio program and telephone service to about thirty locations by the end of 1974.

Today we have three Anik satellites in orbit serving some sixty locations in Canada with a high quality service from the technical standpoint. However, the number of users served is small, a fact which is both a contribution to and a result of the commercial non-viability of the system.

However the under utilisation of the satellite resource - only 9 channels used of the 36 in orbit - has been a cause for major concern and criticism over the last few years. This poor utilisation has been created by the relatively high cost of satellite service which is a function of technology. This cost is based on the need to realise a reasonable return on investment - a requirement under the Telesat Canada Act.

Recently, since it is not possible to achieve a reasonable return on investment under the prevailing institutional arrangements, the Trans-Canada Telephone System and Telesat Canada have signed an agreement which effectively ensures the integration of the satellite system into the national network and assures Telesat of an acceptable return on investment.

This agreement is subject to CRTC approval and hearings are scheduled for April '77.

An important part of the agreement is the design, construction and placing in service of a brand new satellite system employing a similar frequency band to Hermes (12/14 GHz) at a reduced power level.

Current plans exist for this new satellite system to take up a sizeable portion of Trans-Canada voice traffic and also provide services to broadcasters, CATV operators, etc.

Thus by 1980 we will have two operational satellite systems in orbit.

The problems of efficiently utilising this additional national resource (ultimately paid for by the Canadian consumer) are enormous. The Telesat/TCTS agreement is no panacea for a technically exciting but financially troubled telecommunications

system. The only cure is to find useful services for the system to provide. These services can include educational delivery systems.

The normal laws of supply and demand do not prevail in a system jointly owned by the Federal Government and the Common Carriers who are largely Federally regulated. If they did we would see not the extension of the system but its bankruptcy.

This scenario of oversupply with the system now being supported by the Telephone Companies provides an outstanding opportunity to develop new services using tariffs which are a function of system cost and utilization. - an outstanding opportunity for innovative users. An outstanding opportunity for the Canadian educational system?

There is no more successful industry in Canada than the telephone operating entities. Now that the satellite system is part of the network one can expect an aggressive attempt to utilise it to provide new user services.

However, the history of the telephone companies is not to develop new services but to meet the demand. This they do if the new services can be shown to be profitable.

Therein lies the challenge!

1.3 Possible Use of Satellites for Educational Delivery Systems

The utilisation of satellites as a means of extending health care delivery and education has been experimented with in several countries - notably India and U.S.A.

In the past year several Canadian experimenters have availed themselves of full use of the Hermes satellite to undertake experiments in health care and educational delivery systems.

The experience gained in and the enthusiasm generated for satellite delivery systems was much in evidence at the CTS HERMES EXPERIMENTERS MEETING at the Convention Centre in Ottawa early March '77.

The satellite offers many advantages over other transmission means for educational delivery systems especially where video is to be delivered.

Consider these advantages:

a. The major portion of the system - the satellites - is already in place and has tremendous unused capacity.

b. A location can be served by the provision of only one basic addition to the network per location - an earth terminal.

c. The project implementation time is short - an extensive national or provincial educational delivery system could be installed and ready for operation in less than one year.

d. The unique broadcasting capability of satellites is better suited than the point to point system for educational purposes.

e. System reliability is easier to achieve - loss of one station does not affect the network.

f. The satellite system can be designed to provide a better quality than the telephone system - thus enhancing the quality of teaching.

When one considers video transmission on a national basis there is now only one way to go - via satellite.

In the case of voice delivery systems the telephone network could probably be deployed more cost effectively - especially in a province which owns its own telephone system. However, this has yet to be determined.

A key determining factor in the possible deployment of satellites for educational delivery systems to small communities is the prospect of adding other services into the community

Once a basic earth station exists the addition of a channel of television for instance is easily accomplished.

However, there are factors which make it difficult for educational and other small potential users to gain access to the satellite system to meet their requirements. The first is system cost and the second is the institutional arrangements involved in the delivery of satellite service.

This study addresses the costing of two networks thought to be potentially useful for educational delivery systems.

The important issues of how to interface with the institutions involved in the conceptualisation, planning, costing, development of service agreements and finally implementation are not addressed.

That satellites can enhance our educational system is not in doubt. What needs to be established is the demand and then the design of a system specifically to meet that demand.

It is hoped that this study stimulates interest and assists in decision taking by informing users of the potential of satellites to address their needs.

2. SCOPE OF STUDY

The scenario developed in Chapter 1 has motivated the undertaking of this initial study into the possible cost of satellite based educational delivery systems. Two particular types of hypothetical networks are envisaged:

CUSS: National system linking a small number of universities and receiving centres with video and interactive audio return.

PETS: Regional system providing moderate to large number of remote accesses to teaching centres with interactive audio only.

All major components of cost to install and operate such systems are considered, namely

- systems engineering and program management
- lease of satellite space segment
- lease of satellite earth segment
- educational facilities and staffing
- system and terminal operations and maintenance.

Although this study does not elaborate on a detailed system design, cost-sensitive technical factors such as:

- choice of 4/6 GHz versus 12/14 GHz frequency band

- transponder utilization

- earth station size

- video signal quality

- division of responsibility between operating company and user to install and operate system

- operating and maintenance philosophy.

are addressed.

To the extent practicable, the study has been kept general with regard to the exact topology of the two networks. However, in order to render the investigation as realistic as possible, and especially to derive overall costs, it has at times been necessary to make assumptions on approximate number of terminals, coverage area, communications facilities, etc. If the requirements are modified, the reader can derive new costs based on unit costs provided in this study.

It is understood that only a "broad brush" look at the trade-offs surrounding the exact definition of the most appropriate

satellite delivery system is provided here. Some attempt has been made to conceive minimum cost systems satisfying anticipated user requirements. It is emphasized that efficient use of satellite operating company facilities (space segment and earth stations) is the most critical aspect of realizing a cost-effective system. This in turn can only be assured by an overall system definition developed with a clear understanding of both educational requirements and delivery system cost sensitivities, and ongoing participation by the user in the detailed planning, development, and operation of the system.

3. DESCRIPTION OF TWO HYPOTHETICAL EDUCATION DELIVERY NETWORKS

3.1 Canadian Universities Satellite System (CUSS)

3.1.1 Network Topology - CUSS

The network hypothesized will essentially provide the means of transmitting audio and video courses from any of about ten locations to each other and to about a further twenty locations capable of reception only. Each location receiving the audio and video signal will also be fitted with a real-time interactive audio return capability via the satellite.

The locations of the originating stations will be Universities each having a class room (or class rooms) equipped with the necessary monochrome cameras, microphones and loud speaker system such that questions from remote locations can be heard by the originating location. The originating classroom location is assumed to be attended by students so that these students will also have microphones strategically placed to allow interaction between themselves, the lecturer, and participating locations.

The locations for the receiving stations will be Universities or Colleges in the main although it may also be that other non-academic locations might maintain receiving stations where the number of potential students justified

the expense. This classroom will be equipped with a TV monitor microphones and a loud speaker (or headphones).

3.1.2 Utilization of Network

Preliminary analysis on the most cost effective system to serve about ten transmit/receive locations and about a further twenty receive video/transmit voice stations indicates that a system design permitting two simultaneous video signals plus several audio return signals would appear as a reasonable compromise between anticipated demand and effective space segment utilisation.

It is at least a good starting point for the system design.

Such a configuration would permit the transmission of two simultaneous courses originating from any two of the ten locations or would permit two way interactive video between two locations with the possibility of video being received at other locations.

In such a teaching scenario it may then be useful to fit additional receivers to locations desirious of receiving two courses simultaneously.

It is also possible to conduct audio tele-education originating in any of the thirty locations since all locations are equipped

to transmit and receive audio.

It should be noted that such a possibility could potentially lead to the deployment of the receive video/transmit audio locations as course origination points in a regional or sub-regional network.

The promise of two way voice in the network also permits the transmission of course material, tutorial work, library references, etc. using a facsimile machine or other terminal devices. Much of the material such as library references etc. could be sent when courses are not being given thus providing improved system utilization in off-hours.

Thus we could foresee a developing complex network.

3.1.3 Network Control

The CUSS Network itself is of such complexity that a System Control Centre would be established to manage the network. This might be conveniently located at a University originating a large number of programmes.

3.2 Provincial Educational Telephone System (PETS)

3.2.1 Introduction

The Provincial Educational Telephone System (PETS) may be conceived as a network of some 200 locations. To lend realism to the investigation we have decided to use Quebec as an example. Preliminary work has shown that with the strategic placement of about 197 stations, 98% of the population of Quebec would be within 25 miles of a station.

To provide a 197 station network using a satellite delivery system requires significant analysis beyond the scope of this study. Preliminary investigation shows that a satellite delivery system might not be cost competitive with a telephone network based system such as is deployed in the Wisconsin Educational Telephone Network. It may be worth noting that Wisconsin with a population of less than five million has 30,000 students using their network per year. However, the satellite offers other advantages such as the possible addition of other services into a community, better audio quality, rapid deployment, flexibility in planning, etc. so we have decided to cost out a system in which the courses are totally delivered by satellite.

Further investigation would possibly favour a mixed telephone network/satellite network from the economic standpoint.

3.2.2 Topology of the Network

Of the 197 locations of the proposed network we shall assume that about ten locations are to be equipped with two audio channels to permit two courses to be delivered simultaneously. Thus we might have a maximum of twenty forward channels to be delivered over the satellite to any of the potentially 196 receiving locations and as many shared channels as there are courses.

It may be foreseen that any one location might require up to, say, three courses of the twenty capable of being delivered at any one time. Additionally there is a need to transmit course notes, library references etc. Thus each receiving station may be provided with up to four receiving channels.

In order to minimise the need for several classrooms at the local centre it may be appropriate to use headsets to allow mixed courses to be held in one room.

The ten originating terminals would be constructed using a larger antenna to minimise the uplink power from the smaller remote stations. This tends to reduce total system cost, but means two remote stations cannot communicate directly with each other.

3.2.3 Utilisation of the Space Sector

The maximum space sector utilisation is forty channels during peak loading. This is likely to be about 10% of a transponder capacity in the 12/14 GHz Anik C satellite but it may prove to be more cost effective to use more satellite capacity to trade-off with ground terminal costs.

3.2.4 Network Control Centre

With up to forty voice carriers (twenty courses) being handled at any one time there is a need for a Centralised Network Control Centre.

This centre would be similarly structured to the CUSS Network Control Centre and have similar responsibilities.

The PETS Control Centre, however, would be handling a larger number of courses and a larger network. Means would have to be provided for ensuring simultaneous courses from several locations are transmitted at designated frequencies, and courses and corresponding common return channel frequencies are selected appropriately at each receiving station.

This could be effected automatically from the Central Control Station using an automated control system with satellite connection to each terminal in the network. Alternatively,

the transmit only functions could be affected from the Control Station, leaving the individual receive stations to individually manually select one or more "programs" on advertised frequencies. In addition to offering possible cost advantages,this latter approach might actually be preferred if the network were also used for the distribution of several channels of music, university news etc. during course off-hours. In a more extravagant implementation the Control Station could also inhibit multiple illumination and corresponding break up of the return channel following capture by a particular receive location.

4.0 FACTORS AFFECTING COST OF SATELLITE DELIVERY SYSTEM FOR CUSS NETWORK

4.1 Introduction

By 1981 we will have two satellite systems in commercial service in Canada - the current system which has three Anik satellites in orbit serving some 60 locations - and the proposed new services of the Anik C satellites, the first of which is to be launched in 1980 subject to regulatory approval of the Telesat/TCTS Proposal by CRTC.

The existing Anik satellites may be characterised technically as:

- Operating in the 4/6 GHz band.

- Having multiple transponders (12)

- Having an all-Canada beam coverage capability

The planned Anik C series may be characterised technically as:

- Operating in the 12/14 GHz band

- Having multiple transponders (16) *

- Having only regional coverage beams (4) *

There exists, therefore, a choice of two satellite systems on which to base the design and operation of the CUSS Network. This section addresses this question in terms of Space Segment Utilization and Ground Terminal Operational Requirements.

4.2 4/6 GHz vs 12/14 GHz

4.2.1 Basic User Features of Hermes, Anik A Series and Anik C Series

Before considering which satellite system to use for the CUSS Network it is important to realise the basic difference between the Anik satellites (existing and planned) and Hermes (CTS).

Most of the differences arise from the fact that Hermes is an

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* No public information exists on the technical parameters or configuration of these proposed satellites other than a brief comment in the TCTS/Telesat proposal to CRTC.

TABLE 1

	CTS (HERMES)	ANIK A (ANIK I, II, & III)	ANIK C
Beam Coverage	Two spot beams	All Canada	Four spot beaums
No. of Transponders	Two	Twelve	Sixteen
Frequency Bands Used			
Uplink	14 GHz	6 GHz	14 GHz
Downlink	12 GHz	4 GHz	12 GHz
Launch Vehicle Required	Thor Delta 2914	Thor Delta 2914	Thor Delta 3914 (And shuttle later)
Lifetime	2 years	7 years	> 7 years
Ground Stations			
Single Voice Only	1 metre antenna	12' antenna	Not planned
TV Receive	2 metre antenna	12' antenna	?
Frequency co-ord.	Simple	Needs careful selection in urban areas - No problems in Remote Areas	Simple
Technology	Advanced and Still expensive	Mature and widely available	Developing to operational status

experimental satellite whilst the Anik series are designed to serve a large commercial market.

Table 1 indicates some of the basic features of CTS, Anik existing series and the planned Anik C series.

4.2.2 Coverage Offered by 4/6 GHz and 12/14 GHz

The aspect of coverage in a national network is extremely important in the choice of delivery system. In this area the 4/6 GHz Anik satellites are significantly more attractive for the CUSS Network since they can reach all areas of Canada using one (or part of)a transponder as opposed to the 12/14 GHz satellites which require the use of four transponders to effect the same coverage. This fact essentially eliminates the 12/14 GHz satellite from further consideration in the CUSS Network if one assumes that the tariffs would be based on transponder utilization rather than service coverage.

4.2.3 Basic Earth Terminal Requirements

Basic earth terminals which could serve the CUSS Network requirements are approximately similar in antenna size and characteristics. An antenna of about 4-5 m diameter is envisaged for both the 4/6 GHz and 12/14 GHz application in the majority of locations though larger antennas might be more cost effective

at transmit locations.

Earth station equipment operating in the 4/6 GHz is less expensive, more reliable and more widely available currently than 12/14 GHz equipment.

4.2.4 Siting of Terminals

The 4/6 GHz earth station presents a problem of siting since the satellite frequencies are shared with common carrier terrestrial radio and careful co-ordination has to take place at the planning stage to ensure that one system does not interfere electrically with the other.

Initially most 4/6 GHz earth stations had to be located some distance from the areas they were intended to serve. For example, Allan Park is about 90 miles from Toronto.

Over the last few years much operational experience has been gained and 4/6 GHz earth stations have been located and used on a temporary basis in urban locations in Toronto, Montreal, Ottawa, Vancouver, Calgary etc.

Currently, Telesat have in place a service transmitting and receiving colour television between Calgary and Allan Park to extend the TCTS teleconferencing network. The earth station in Calgary has been installed in the roof of a building.

Earth terminals operating at 4/6 GHz located in University campuses will have to be carefully sited and co-ordinated. There is little doubt that they can be so accommodated.

4.2.5 Summary

The advantages of using the 4/6 GHz band for the CUSS network far outweigh the one disadvantage - the need for careful frequency co-ordination.

4.3 Space Segment Utilization

4.3.1 Cost of Transponder Lease

One complete transponder of the current Anik satellites can be leased full time for a cost of about $2,000,000 per annum. At present, only complete transponders can be leased from Telesat. The new TCTS/Telesat agreement further restricts leasing to common carriers only.

However, it may be that when Telesat becomes a member of TCTS the standard telephone company practice of charging on a time and use basis will be followed.

Thus if $2,000,000 is required as revenue to ensure a reasonable return on investment by the operating company and if there is a user demand of, say, twenty hours per week for fifty weeks the transponder lease cost would be $2,000 per hour for the complete

transponder.

It seems reasonable to propose that any time beyond 1,000 hours per year would be at no further cost.

4.3.2 Cost Sensitivity to TV Signal Quality

The CUSS system is foreseen as a monochrome TV service rather than full colour with its attendant increased operating and capital costs. The signal quality to be delivered at each location would be about the same quality as that normally achieved on cable TV. Postulating monochrome and a significant lowering of transmission standards from that normally used by common carriers presents the opportunity to design a low cost delivery system which optimises space sector utilisation by permitting two TV signals plus several voice channels to be transmitted simultaneously through one transponder.

Thus the CUSS Network could use either half a transponder (one television channel and associated two way audio); or

could transmit two programs simultaneously from different originating points; or

could effect two way video and audio transmissions.

4.3.3 Use of Spare Capacity at Lower Cost

In para. 13(2)b of the Telesat TCTS Memorandum of Agreement made as at 31st day of December 1976 it is stated that "when the prime capacity has been fully committed, secondary capacity, with no in orbit back up, will be available at a rate which recognizes the possible interruptible nature of the capacity".

This notion is similar in charging concept to that which has been in force in Intelsat System for the last few years. The Intelsat rates were made sufficiently attractive to have encouraged about fifteen countries to use Intelsat satellites for national communications using 1/4, 1/2 or a complete transponder. The complete transponder can be leased currently for $1M.

4.3.4 Use of Multiplexed Video Signals

It has been demonstrated* that it is possible to multiplex at least four video signals for transmission over any system capable of currently carrying one TV signal. Such a technique results in a reduction of the transmission costs by a factor of four at the expense of video quality.

A factor of four reduction in the space segment charge would result in a per hour charge for a TV signal as follows:

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* PSC Learning Experiment on CTS between Ottawa and Memorial University, Newfoundland

a. $250 per hour provided two simultaneous carriers were transmitted through one transponder.

b. $500 per hour if only one carrier were transmitted through the transponder.

4.3.5 Use of Digital Transmission Techniques

It is possible to utilise digital transmission techniques with redundancy removal to transmit TV signals. Such techniques have been used in the Carleton-Stanford CTS Experiment.

Essentially the signal is processed electronically to reduce the performance requirements of the transmission link. This is achieved with only a small sacrifice in video fidelity, but at significant hardware cost*. Such a technique, like an increase in antenna size, reduces the space sector charge at some increase in ground station hardware costs.

4.3.6 Summary

The current practice of only leasing complete transponders to common carriers has not encouraged innovative users to look to satellites as a means of service delivery. Neither has the in-orbit over capacity encouraged the institutions or government to consider cost effective use of transponders.

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* The digital television codec used in the Carleton-Stanford experiment costs about $75,000 (qty. 1) or $50,000 (volume quantities). In addition, a high speed modem costing about $30,000 is required. Future reductions in these prices are expected.

There are simple technical methods of improving the efficiency of utilization of transponders which have not been encouraged. It is clear that only user pressure will provide more attractive charging rates - especially in the over supply situation anticipated in the next few years.

4.4 Ground Terminal Operational Requirements

4.4.1 Location

To ensure a cost effective system the ground terminals should be located close to the user area. This is not expected to present any major difficulties other than the normal reluctance of an operating company to locate their plant in user's premises for security, access and other reasons.

Co-location with user area will ensure:

- availability of power
- least backhaul distance
- possible use of existing buildings
- easy access for maintenance

Installing the facility close to an existing building should also provide some additional natural shielding from possible interfering signal sources.

In some cases, roof top mounting may be appropriate.

4.4.2 Power Requirements

From the viewpoint of power consumption a complete transmit/receive terminal requires less than 3kVA. The receive only stations can be fed from a standard single phase supply.

4.4.3 Maintenance

All stations in the network will be designed for completely unattended operation and with a high degree of reliability.

Not more than 1 to 2 service calls per year plus two routine check visits are anticipated.

There is no reason that university staff technicians could not maintain the station.

4.4.4 Operational Control

System operational control should be effected from one national centre

- either based on a University or centralised with other operating company services.

If a University is chosen as the System Operational Control Centre then the choice might be based on such factors as:

- volume of system usage from that University

- technical infrastructure capability

- proximity to operating company operations and maintenance centre.

5.0 Factors Affecting Cost of Satellite Delivery System For PETS Network

5.1 Introduction

The tradeoffs between space segment and ground segment in an audio delivery system employing large numbers of user terminals such as PETS are substantially different from those in the CUSS Network.

The natural tendency from the economic standpoint is to reduce the size of the ground terminals to effect low cost per unit.

The biggest problem arising in this area is that of protection of adjacent satellites using the orbit because of deployment of small aperture, wide beam width antennas. Satellites of all nations have to be protected. This is effected through agreed international technical standards.

The deployment of small aperture terminals at either 4/6 GHz or 12/14 GHz raises questions which might not be adequately answered for several years since studies by all nations are still in progress.

5.2 4/6 GHz vs 12/14 GHz

5.2.1 Coverage offered by 4/6 GHz and 12/14 GHz Satellites

Since the PETS Network is envisaged as a regional network the coverage available from the existing and planned satellites appear adequate at both 4/6 GHz and 12/14 GHz.

5.2.2 Siting

In the case of the 4/6 GHz earth terminals a small terminal, say, 3 metres deployed in large numbers would be a difficult and costly proposition. Also the prospect of gaining regulatory acceptance in terms of the orbit protection requirements is unlikely.

It would therefore appear more rewarding at this stage to concentrate on the use of the 12/14 GHz band for the PETS Network.

However, if 4 GHz receive only terminals could be deployed with telephone call up return channels, a distribution system via satellite could be effected in a very economical fashion. It is felt, however, that for the student to have to dial in with questions is a poor feature from the interactive point of view and would seriously impair the system effectiveness.

5.3 Space Segment Utilization

5.3.1 Method of Access

The PETS System would essentially be a single channel per carrier system operating mostly in a broadcast mode with interactive capability.

The space segment requirement, therefore, is for the lecturer's voice being carried over a single broadcast voice channel and delivered with a quality substantially better than that available on the telephone network. Thus near broadcast quality should be postulated.

The return channel to the lecturer is seen as one multi-access channel on a first come first served basis being transmitted from the user earth terminal to the larger earth terminal located on University campus or major teaching centre. Any questions transmitted to this centre would be re-broadcast and heard by all students.

It would then be possible to structure the system design to optimise the use of the space sector and minimise the up-link audio power requirements of the user terminal thus reducing its cost.

The space segment cost in the PETS System is not expected to be significant in comparison with total earth station costs.

5.3.2 Summary

The PETS Network requirement might well be more effectively fitted by the deployment of small aperture earth stations operating in the 12/14 GHz band. It is to be noticed, however, that there is a lack of "off the shelf" hardware and station costs are likely to be higher as a consequence.

6.0 Proposed Delivery System for the CUSS Network

6.1 User Requirements

The basic requirement is to originate monochrome television of the lecturer and his environment at about ten Canadian Universities. It will then be possible to distribute this lecture simultaneously in real time to all thirty or so Universities and other locations involved in the network. A two way interactive voice and document transmittal facility will also be included.

The quality requirements of the delivered video signal should be no worse than the average cable TV picture.

The audio should be substantially better than the telephone network and approaching broadcast quality.

The operation of the camera, monitors, microphones, loudspeakers, etc. should be such as to be switched on and set up by the lecturer or an assistant prior to the lecture.

The earth stations will be designed for completely unattended operation - which concept has been well demonstrated in the Telesat System.

6.2 System Control Centre (S.C.C.)

The system control centre will have the basic responsibility to ensure the smooth day to day operation of the CUSS system.

To effect this the Centre will be responsible for:

a. Program planning on a National basis

b. System utilization and network operation

c. Advising all users on operations

d. Developing system control procedures

e. Investigating and correcting operational problems.

Each University capable of transmitting would have a representative reporting to the System Control Centre to ensure effective co-ordination of the network. It is expected that this representative would be a staff member of the University and have been previously engaged in the Network Development Planning Team.

The technical facilities comprising the physical plant at the network control centre would include:

a. A telecommunications centre - probably with phones and telex machine.

b. A supervisory display board showing the network status.

c. The means of remotely controlling one or two active originating stations - which would act as master stations in their program distribution.

d. A computer control system to ensure automatic control of the network and store program information.

e. The appropriate audio and video monitoring equipment.

f. The means of network fault logging.

The system control centre will not duplicate services provided by the Common Carriers but will essentially monitor and control network operation and represent the interest of the users in the operation of a reliable and effective system.

6.3 TV Transmit/Receive Earth Station

Since the lease cost of any earth station is a function of the capital cost of the station provided, the prudent user should postulate a design which meets his requirements with the minimum amount of leased equipment. Normally the annual

leased cost of an earth station is around 30-40% of the capital cost.

The prudent user should also undertake as much of the planning as possible and provide at least the following to reduce the lease costs:

a. The site - land and infrastructure

b. The power feed to the earth station

c. The antenna foundation

d. The shelter to house the earth station equipment.

e. Assistance to the installation.

He should also be prepared to provide the hydro and phone service from his budget to reduce operating costs.

The earth station envisaged for the purpose would consist of:

a. An 8M Diameter Antenna

b. A transistor low noise receiver

c. A 40W TWT high power amplifier

d. Up and down conversion equipment

e. An F.M. modem for TV

f. Audio sub carrier modem

g. A voice return receiver.

If the programming builds up to a significant extent than additional transmitters and receivers should be added.

For example, one University might wish to conduct two courses simultaneously. The additional equipment could also serve as back up.

6.4 TV Receive Earth Station

Locations fitted with TV receive only capability and the means of return voice channel would consist of:

a. 4M Diameter antenna

b. A transistorized low noise amplifier

c. A TV downconvertor and demodulator

d. An audio subcarrier receiver

e. A voice return transmitter

Again, the site, etc. should be provided by the user to reduce lease costs.

The voice return transmitter would be so structured as to be settable in frequency to match the receiver to which it will connect at the program origination location.

6.5 Space Segment Utilization

It is proposed that the space segment is so utilised as to permit it to carry two TV signals with audio plus two return voice channels. The frequency plan for this concept would use the centre of the transponder to effect the voice return channels thus easing the frequency co-ordination with terrestrial microwave.

6.6 Summary

To achieve a cost effective CUSS Network it is essential that the user design his system with a good understanding of charging philosophy. It is also possible for the user to undertake a significant amount of the work on his capital and operating budget to save lease costs from the operating company.

A System Control Centre is essential to the orderly operation of any National Network.

This S.C.C. should be professionally staffed by experienced personnel capable of running a high class operational network.

The equipment specified for the earth station is widely available and well developed.

7. PROPOSED DELIVERY SYSTEM FOR THE PETS NETWORK

7.1 User Requirements - PETS

The basic requirement is to originate a good quality audio service from, say, ten teaching locations capable of serving up to two hundred locations in an interactive mode. Practically, the requirement may be for each of the ten teaching locations to be equipped to provide the means of transmitting two courses simultaneously. Thus a maximum of twenty simultaneous courses could be put on.

Realistically the number of simultaneous courses may be much smaller - say three - especially at the start up of the operational system.

The audio quality to be utilised should be significantly higher than that achievable by the telephone network to enhance the educational effectiveness of the system. Such improved quality does not incur any significant cost penalty in a satellite system.

The students would be located either in a classroom at the remote community or the service could be extended from the satellite ground terminal into the home if appropriate. This extension would incur service quality and cost penalties not addressed in this study.

The classroom would be equipped with headsets and microphones to provide the ability to deliver several courses simultaneously into a common classroom. If only one course were being delivered or if more classrooms were available, then loudspeakers and microphones could be used.

The cost tradeoffs in providing these user facilities would be quantified when the detailed requirements were being established.

7.2 System Control Centre - PETS

The network envisaged would require a Network Control Centre similar in concept and effecting the same control as that postulated for CUSS.

Since a large number of receive locations, courses and transmissions are envisaged, there would be a greater bias towards administrative control rather than technical control.

The technical delivery system would be highly automated to reduce technical operating costs.

The System Control Centre would also control the maintenance program of the very large amount of equipment deployed in the network.

7.3 Teaching Station

A typical teaching station would comprise a 2-3 metre fixed antenna with the capability of transmitting at least two courses simultaneously from either classrooms or small studio appropriately equipped with a microphone/loudspeaker system.

Up to three receivers might be fitted since the teaching location might also take courses from other locations and the interactive mode is assumed.

Since no siting difficulty is anticipated the antenna would be located on or adjacent to the building containing the classroom and most of the technical equipment would be housed in the user's property.

The same arrangements as CUSS to minimise lease costs would be taken.

7.4 Learning Station

The learning station would be similar to the teaching station in most respects except for the number of individual receivers fitted which is a function of the desired number of simultaneous courses.

7.5 Network Signalling and Switching

The large number of courses anticipated to the large number of perspective learning locations implies the need for an automated signalling and switching system to configure the network as required to ensure that learning locations are set to receive the planned courses.

This is a relatively simple technical problem which requires interactive control between firstly the teaching centres and the System Control Centre (PETS) and then from the System Control Centre to the learning locations.

The simplicity arises from the fact that changes of state occur at infrequent and controlled intervals - possibly hourly and on the hour. A microcomputer based system is envisaged. Verification can also be easily accomplished via voice return links in case of doubt.

7.6 Summary

The PETS earth station required are relatively simple and would be controlled from a System Control Centre by automated means to ensure efficient low cost operation.

8. SYSTEM COSTS FOR CUSS NETWORK

8.1 Introduction

There are four basic elements of costs to be addressed in this study:

- the lease costs of the space sector

- the cost of the earth stations - both lease costs and capital operating costs

- the auxiliary equipment costs such as camera monitors and audio equipment

- maintenance and operating costs.

Also included are the costs of system design and negotiating agreements with TCTS/Telesat - an important consideration and one which is assumed to be handled by a team appointed by the educational institutions desirous of setting up the delivery system.

8.2 Space Sector Costs

It is assumed that the cost of one transponder will be $2,000,000 per year. Assuming the equal use of thirty locations then each participant will have to pay $67,000 per annum.

If the charges are based on time only then $1,000-2,000 per hour per transponder may be appropriate. The costs can therefore either be negotiated on a bulk basis or by the hour. The best user approach can only be determined after a need survey is carried out.

8.3 Cost of Earth Segment of Satellite System

8.3.1 Cost of Transmit/Receive (Teaching) Station

The basic kit of hardware for each Transmit Receive Station comprising:

One Antenna System (8 M)
TV Transmitter
TV Receiver
Audio Transmitter
Audio Receiver
Supervisory Equipment
Control & Signalling Equipment

Power and miscellaneous equipment

Documentation

is estimated to be $120,000

Additional local costs comprising

Site Development

Equipment Shelter

Installation

Shipping

are estimated to be around $30,000 on average.

In addition an engineering and management cost component expended by the Project Team of $12,000 would be attracted.

Thus a complete earth station capable of transmitting and receiving one video and one audio would cost

Hardware Kit	$120,000
Site Development and local costs	30,000
Engineering and Management	12,000
	$162,000

Additional equipment fitted would cost as follows:

Additional TV Transmitter	30,000
Additional TV Receiver	8,000
Additional Audio Transmitter	5,000
Additional Audio Receiver	4,000

8.3.2 Cost of Receiving (Learning) Station

The basic hardware kit for each Receive Station comprising:

One Antenna System (4-5M)
One TV Receiver
One Audio Receiver
One Audio Transmitter
Control and Signalling, etc

is estimated to cost $40,000

Additional local costs comprising:

Site Development
Equipment Shelter
Installation
Shipping

are estimated to be around $15,000.

In addition an engineering and management cost component expended by the Project Team of $10,000 would be attracted. Summarizing,

Hardware Kit	$40,000
Site Development and local costs	15,000
Engineering and Management	10,000
	$65,000

Additional equipment fitted would cost as follows:

Additional TV Receiver	$8,000
Additional Audio Transmitter	5,000
Additional Audio Receiver	4,000

8.3.3 Additional Costs of System Control Station

The System Control Station would have to be equipped with the means of overall network control and would require equipment and facilities additional to that required by the other Transmit Receive (Teaching) Stations.

This equipment would comprise:

- Central Signal and Switching Equipment
- Central Supervisory and Monitoring Equipment

at a total estimated cost (including software) of about $150,000.

8.3.4 Audio/Video Equipment

The requirement here is discussed in some detail in Appendix A, and is subject to many variables. Typical capital costs for a teaching centre with a 24 student classroom and a receive only centre also with a 24 student classroom are

One course transmit/receive	$10,000
One course receive only	$ 4,550

This does not include the provision of a facsimile service, which would cost $1,500 (xerox slow telecopier) to $12,000 (Rapifax, high speed, automated facsimile machine).

8.3.5 System Maintenance and Operating Costs - Station Complex

The major component of System Maintenance cost could be attracted by the System Control Centre which would be staffed by technical and administrative staff.

Typical annual costs might be:

Network Director	30,000
Technical Supervisor	25,000
Technical Supervisor	25,000
Technician (1)	14,000

Production Supervisor	15,000
Scheduling Clerk	10,000
Secretary	10,000
Space 5,000 sq.ft @ $10	50,000
Office Expenses	10,000
Travel	5,000
	$194,000

assuming that Telesat were responsible for all ground station maintenance. Operations and maintenance would also attract some cost on a per station basis due to the need for local performance monitoring and fault reporting, and possibly line up just prior to lecture delivery. Operational experience over the CTS and Telesat system* indicates these functions can be performed by relatively technically unskilled (i.e non-dedicated) personnel, and hence these costs can be assumed to be rather small:

Transmit/Receive Terminals not colocated with maintenance centre 9X$1,000	9,000
Receive only Terminals 20X$400	8,000
	$17,000

*Ref. A.D.D. Miller, "Operational Experience with Small Unattended Television Receive Earth Stations", AIAA 5th Communications Systems Conference, Los Angeles, April 22-24, 1974.

In addition modular equipment spares would be required together with an equipped repair facility. The following costs are estimates:

Equipping of System Spares	200,000
Equipping of Repair Facility	100,000
Annual cost of maintaining Repair Facility	10,000
Annual cost of Spares Replacement	25,000

Thus the total annual cost of System Maintenance and operation might be:

Staff and space	$211,000
Maintenance of Repair Facility	10,000
Maintenance of System Spares	25,000
	$246,000

The costs to run of each station are low (power consumption Teaching Station - 6 kVA, Learning Station - 1 kVA) and are assumed to be borne by the user.

8.3.6 Instructional Costs

Instructional costs, including teacher's salary, overhead, supplies and services, and possibly classroom space have not been included as part of the study per se, although they are

discussed in Appendix A. These costs can fluctuate rather wildly depending on the accounting (see Section 4.4 Appendix A) performed, but they are not greatly different than those normally associated with the delivery of university courses.

8.3.7 Summary

The basic CUSS Network could be put into operation within two to three years at a capital cost as follows:

Qty 10 Transmit Receive one simultaneous course teaching centres at $160,000	$1,600,000
Qty 20 one simultaneous course receiving centres at $60,000	1,200,000
System Control Centre Additions	150,000
System Engineering & Management	320,000
Set of system spares	200,000
Equipping of repair facility	100,000
	$3,570,000

Assuming that most of this system were installed by Telesat which applies an annual lease charge of between 30% - 40% of total capital cost, the annual cost of this hypothetical station network utilizing one 4/6 GHz satellite transponder of an Anik A or B satellite on a full time basis can be summarized as follows:

Lease of ground Segment Facilities	1,071,000 to 1,428,000
Lease of Space Segment	2,000,000
System Maintenance and Operations	246,000
Total Annual Cost	$3,317,000 to $3,674,000

A total annual cost of $3 1/2 million is therefore anticipated. This includes only the cost of the teacher to student delivery system, and not the educational costs themselves. It should also be noted that no Federal or Provincial Sales Taxes have been included in the hardware costs.

9. SYSTEM COSTS FOR PETS NETWORK

9.1 Introduction

The same basic approach to costing can be applied as in the case of the CUSS network. Again the four basic cost elements addressed are:

- the lease costs of the space segment

- the earth station costs (capital and/or lease)

- the auxiliary audio equipment

- system maintenance and operation

Also included are costs of system design and negotiating agreements between Telesat and the telephone company serving the region of interest which is Bell Canada in the example used.

It should be noted that the estimates of cost are somewhat more difficult to make when working with the advanced technology implicit in the 12/14 GHz band.

9.2 Space Sector Costs

The new Anik 'C' satellites are assumed to be more cost effective than the original Anik satellites. Thus let us assume that the annual lease of a transponder might be say $1.5M. The system hypothesized could possibly be deployed using less than 10% of transponder capacity. Thus the space segment might be $150,000 per annum. Shared between about 200 locations this comes to about $750 per year per location for the space segment for full time satellite service.

9.3 Cost of Earth Segment

9.3.1 Cost of Teaching Stations

The basic kit of hardware for each teaching station comprising:

One antenna system (4M)
One 4 channel voice transmit system
One 4 channel voice receive system
Supervisory system
Control and signalling system
Power and miscellaneous equipment

is estimated to cost about $100,000 in quantity ten. It would be a special design.

Additional local costs comprising

Site Development
Equipment Shelter
Shipping
Installation, etc

are estimated at about $10,000.

In addition, an engineering and management fee of about $12,000 would be attracted per station.

Thus a complete earth station capable of originating four audio courses simultaneously could be designed, procurred and installed at a cost of:

Hardware kit	$100,000
Site Development and local costs	10,000
Engineering and Management	12,000
TOTAL	$122,000

Additional equipment fitted would cost as follows:

Additional Transmit Channels (up to a maximum of 8)	$7,000
Additional Receive Channels	4,000

9.3.2 Cost of Learning Stations

The cost of the basic hardware kit assumes not only some 200 stations in Quebec but also the establishment of other similar systems. Thus we will use costs based on a continuous production run of 1,000 units to serve the total Canadian need.

The basic hardware kit for each learning station comprising:

Antenna (2M)

Two Channel Receiver

Single Channel Transmitter

Signalling and Control System

is estimated to cost about $15,000.

Additional local costs attracted are estimated at about $4,000.

In addition the engineering and management cost expended by the project team would be less than $1,000.

Thus the cost of the complete, installed learning station would be:

Hardware kit	$15,000
Local Costs	4,000
Engineering and Management	1,000
TOTAL	$20,000

Additional equipment fitted would cost as follows:

Additional Receiver	$1,500
Additional Transmitter (up to 4 maximum)	4,000

9.3.3 Additional Costs of System Control Station

The additional costs of the System Control Station would be somewhat greater than the CUSS case since a more elaborate status reporting and control system would be implemented.

The estimated costs are about $200,000 for hardware and software.

9.3.4 Audio Equipment

The audio system at the learning stations should be supplied from a central pool to achieve the benefits of standardisation and bulk purchase. Under this assumption a basic allowance of $1000 per receive location would be appropriate. Similarly, a basic cost of $2000 per teaching station is assumed which permits two courses to be conducted simultaneously. Appendix B discusses in further detail more extravagant terminal equipment options and their cost. It is likely that the costs quoted here and in Appendix B could be reduced by large scale procurement and possibly special purpose development of audio equipment for the PETS system.

9.3.5 Maintenance and Operating Costs

The following annual maintenance and operating costs for a basic network are estimated

System Control (central office facility)	$200,000
Local supervision, maintenance and reporting	50,000
Annual cost of maintaining repair facility	10,000
Annual cost of spares replacement	40,000
	$300,000

The cost of power and maintenance is negligible and is assumed borne by the user.

9.3.6 Summary

The basic PETS Network could be implemented within 4-5 years at a capital cost of:

Quantity 10 Teaching stations	1,220,000
Quantity 200 Learning Stations (inc. spares)	4,000,000
System Control Centre Additions	200,000
Equipping of Repair Centre	100,000
System Engineering & Management	320,000
Audio Equipment $1000 X 220	220,000
TOTAL CAPITAL COST	$6,060,000

Assuming that this system was leased at an annual charge of 30% of capital cost then the total system might be leased for around $1,818,000 from the telephone company.

Thus the total cost per receive location per year might be computed as

Space Sector (150,000/200)	750
Ground Sector (1,800,000/200)	9,000
System Maintenance (300,000/200)	1,500
	$11,250

This assumes the provision of a single basic audio teleconferencing unit at each receive location, and two at each transmit location. The costs of providing additional teaching facilities such as facsimile, graphics, etc. are given in Appendix B.

A total annual cost of about $2 1/2 million is therefore anticipated to install and operate a network of about 10 teaching stations and 200 learning stations leasing part of an Anik C 12/14 GHz transponder. As in the case of the CUSS system, only the delivery costs, and not the educational costs, have been considered, and no Federal or Provincial Sales Taxes have been included in the hardware costs.

APPENDIX A

INFRASTRUCTURE COSTS FOR CUSS NETWORK

1. INTRODUCTION

This investigation is not based on a particular fixed system. A general approach is taken in which the size of the major system components can be varied, and the total system cost assigned on a per unit basis as a function of size and configuration.

We are concerned with "delivery system" costs, not with the base academic costs of establishing and presenting a course. However, some care must be taken that some delivery costs are not hidden in the base costs, or vice-versa. As well, costs are meaningful only on a comparative basis, e.g., incremental costs of the delivery system vs the base cost of the course, -or the cost of a single course given simultaneously at many sites vs many courses. As well, the delivery system involves more than telecommunications. The costs of course management, local tutors and the like, are very real. Consequently, our approach will necessitate some very general educational costing.

2. THE MODEL

Except for the extent of its geography, the successful educational television system at Stanford University, located in California just south of San Francisco, serves as a model for the system being studied. At Stanford, a four channel, black-and-white broadcast system is used to distribute instructional television throughout the San Francisco-Oakland Bay region. Their approach is based on regular credit courses presented to an on-campus class, with television providing the opportunity for off-campus students to attend the same classes. The network is financed by a supplementary fee paid by the off-campus students.

Unlike telephone-based systems, this approach does not rely on special courses for remote students. No special training is required for the lecturers, and the system accommodates to conventional lecturing styles. Some lecturers develop special approaches, and lecturers tend to be better prepared than those in the ordinary classroom. That can cause a heavier work load on the lecturer the first time the course is given, but after that initial transient the demands on the lecturer are conventional. The success of the system is demonstrated in its evaluation over a 10 year period to a fully scheduled 4 channel system with some 1500 yearly registrants.

Begun to accommodate graduate electrical engineering courses, the network now serves a broader audience, but the emphasis continues to be on graduate and upper level courses.

During the 1976-77 academic year, the network was extended to Carleton University, Ottawa by means of the Communications Technology Satellite, Hermes. Experience gained in that experiment is reflected in this study.

3. THE NETWORK

A purely hypothetical network is contemplated which comprises T stations capable of both transmission and reception of video signals, and R stations capable of reception only. All stations transmit and receive audio signals. Each system channel consists of one-way video and two-way audio, and there are C such channels available for assignment.

Total system utilization is not assumed. Time zone differences, disinterest in the subject matter and finite antenna "footprints" (areas where the satellite signal may be received)* at any particular operating time ensures less than 100% utilization.

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* This applies at 12/14 GHz only.

Inter-institutional course exchanges are assumed, so all transmitting stations are taken to be universities or colleges. However, in addition to these, other establishments might maintain receiving stations (e.g., Chalk River).

4. COSTING THE NETWORK

The costs of such systems are readily classified into several sections: satellite transmission costs, ground station costs, television distribution costs, incremental academic costs, and basic academic costs. Each of these cost categories are assessed in terms of:

a. capital installation costs

b. annual operating costs to control, maintain, and replace capital items

c. other operating costs

However, alternatives exist in the various categories and they are not independent. For example, ground stations costs are dependent on satellite power and antenna configuration, while ground station and distribution costs are dependent on whether analog or digital video is used.

Although options exist within these categories, they are basically independent. The following sections will review each of these, and in a fifth section the results will be combined and analysed.

4.1 Transmission Costs

This aspect of the study has been covered in the body of the report, which concluded that the 4/6 GHz frequency band is more appropriate for a national network of this type. Annual costs in terms of T, R, and C are provided in Chapter 8.

Each receive-only station needs one TV, one audio channel and possibly a facsimile channel input, and an audio channel output, for each classroom; while the need for facsimile implies additional terminal equipment, it does not mean another communications channel providing the audio link can be shared for this purpose. For an originating classroom, an output TV channel and facsimile channel are required as well.*

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* Note that since facsimile machines are two-way devices, the receiving station can also be fitted to transmit facsimile (over its audio return channel) with virtually no incremental cost impact.

Such interactions tend to complicate the cost study, and in order to eliminate or at least minimize this, the following definitions are made:

1. Transmission begins and ends with a conventional video signal, as does audio, so transmission costs include both the satellite, the satellite ground stations, and any special signal processing equipment.

2. Distribution includes all audio and video equipment needed for both generation and viewing of the television pictures, and special classroom reconfigurations.

3. Incremental academic costs include all those expenses needed to sustain the remotely located students which are extra to the costs of the course were those students not present.

4. Basic academic costs are the costs of the academic courses were there no remote students.

As well, the costs of all facilities except those leased from the satellite operating company (an annual lease charge of 30% - 40% of total capital cost is more appropriate in this case) are translated to an annual cost on the basis that earth-based electronic equipment, given good maintenance, has a 10 year life time.

4.2 Distribution Costs

While it is quite possible to engage in extensive classroom redesign in the process of installing instructional television, this is not necessary and was not done in the CTS experiment. The simple addition of TV monitors to a conventional classroom is sufficient for receiving television instruction; origination requires the addition of TV cameras as well.

Basic configurations are shown in Figures 1 and 2, and diagrams of the two distribution networks are given in Figure 3.

Some choice exists in the degree of sophistication of these facilities, so several alternatives are costed in the tables following this section. Each table begins with a general description of the facilities provided, then the capital costs, including installation, are given. As there are fixed costs as well as costs dependent on the number of classrooms equipped, costs are given for one, two and three classroom configurations.

Operating costs refer to the maintenance of the system and to the technical operation of the ground station, the audio and video distribution network, and the control centre. Most costs are for personnel, and it is assumed that these individuals are already employed at the institution or are available on hourly rates. The amounts shown, therefore, are either

portions of the salaries of full-time personnel, or part-time salaries.

Fixed operating costs are associated with maintenance, and per-course costs with technical operations during lecturers. These are taken to be in a "3 lecture hours per week for 12 weeks" format.

Academic costs cover teaching assistants and lecturers. Based on CTS experience, each course being received is supported by two teaching assistants as tutors and resource people at a $1500 cost. Alternatively, if a faculty member acts as the local tutor he is assigned a 1/2 term course credit against his teaching, has a single teaching assistant, and the cost is the same (as is explained in greater detail later). These individuals are assumed to handle all local arrangements for the course including marking examinations and assignments.

Course origination is taken to cost $2250 for the lecturer and $750 for a teaching assistant. In all cases, other routine costs of organizing and conducting the courses are taken to be included within the institutional overhead. Typical costs are given and would be somewhat less for small classes and larger for those with larger enrolments. Based on Stanford experience, lecturers adapt quite quickly to teaching through television, but the lecturer rate given above includes a 50% premium for

additional course administration due to the remotely located students.

Cost tables now follow. To the capital cost of each complete station should be added $12,000 for a high speed automated Rapifax facsimile unit. (A slow telecopier can be purchased for about $1,500; however, the very slow speed is probably unsuitable in an interactive or instructional environment).

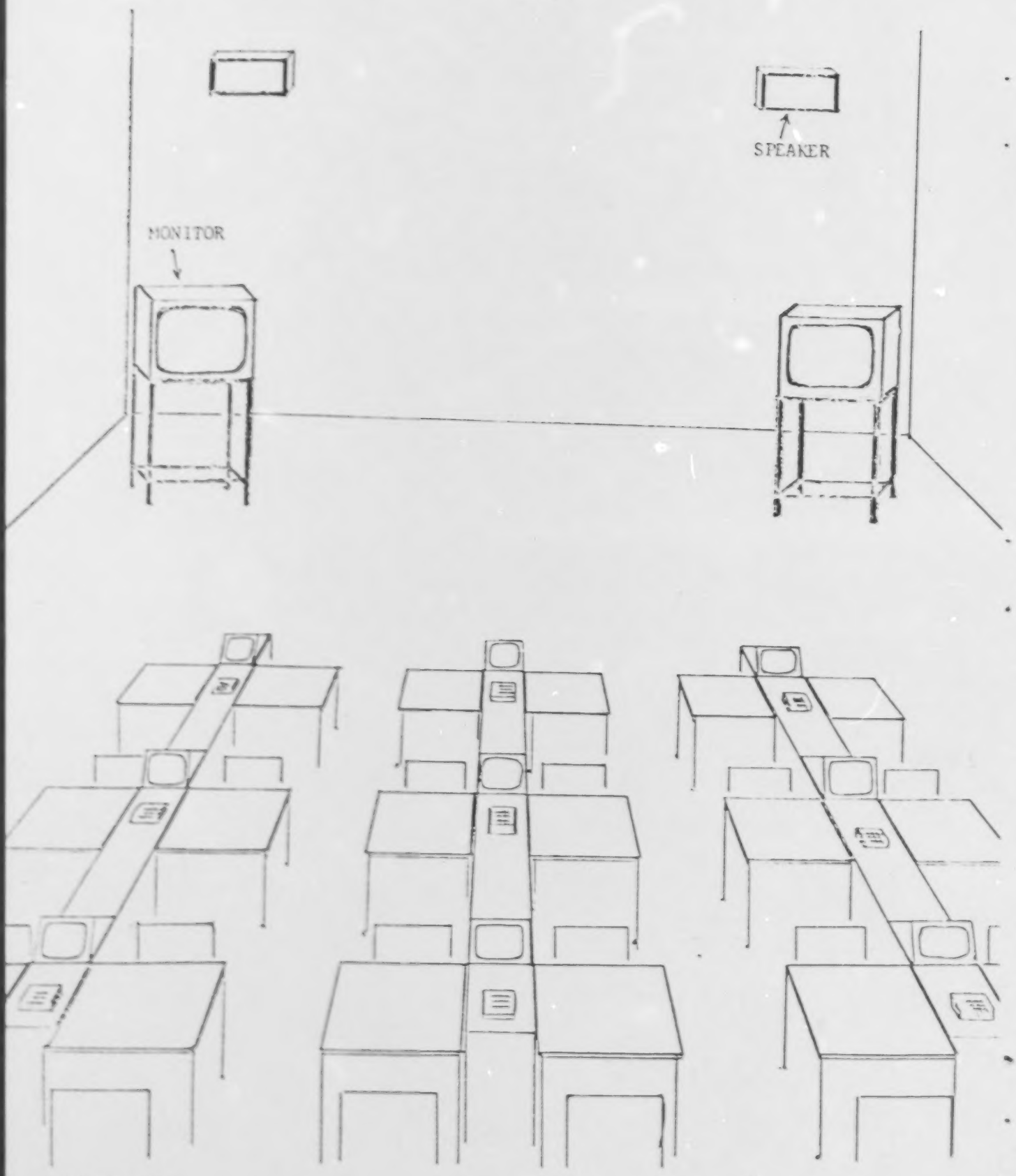

Figure 1
Classroom for reception only

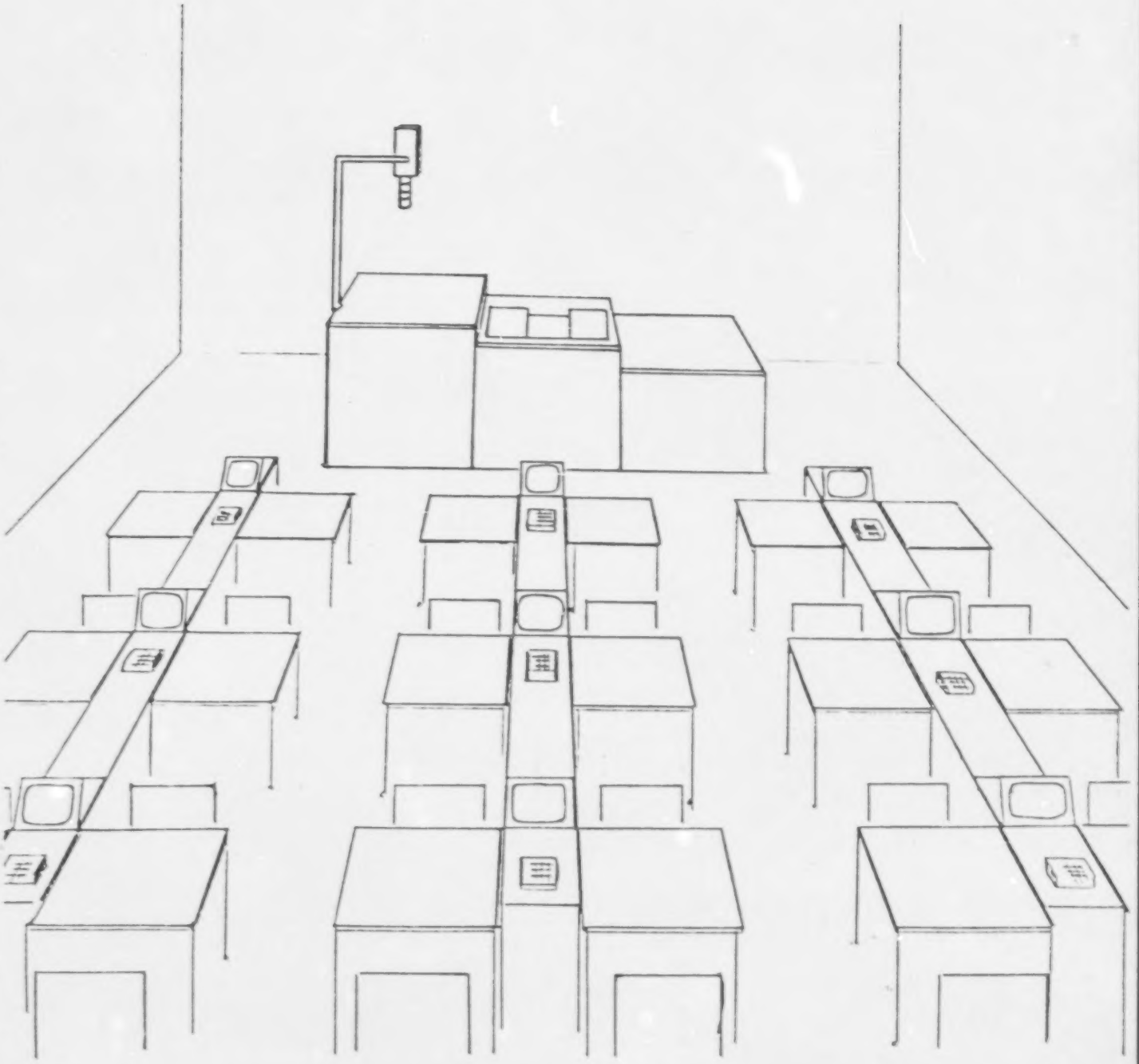

Figure 2
Classroom for reception or origination

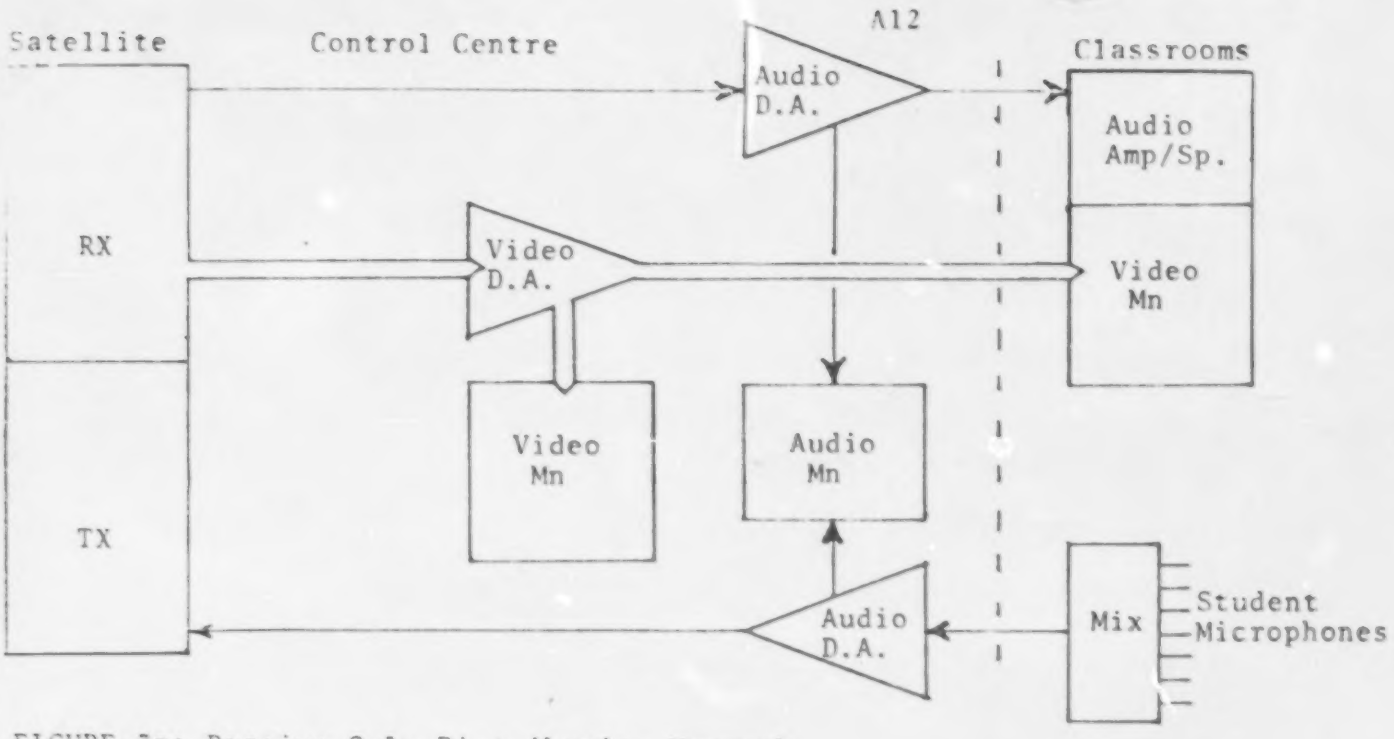

FIGURE 3a: Receive Only Distribution Network

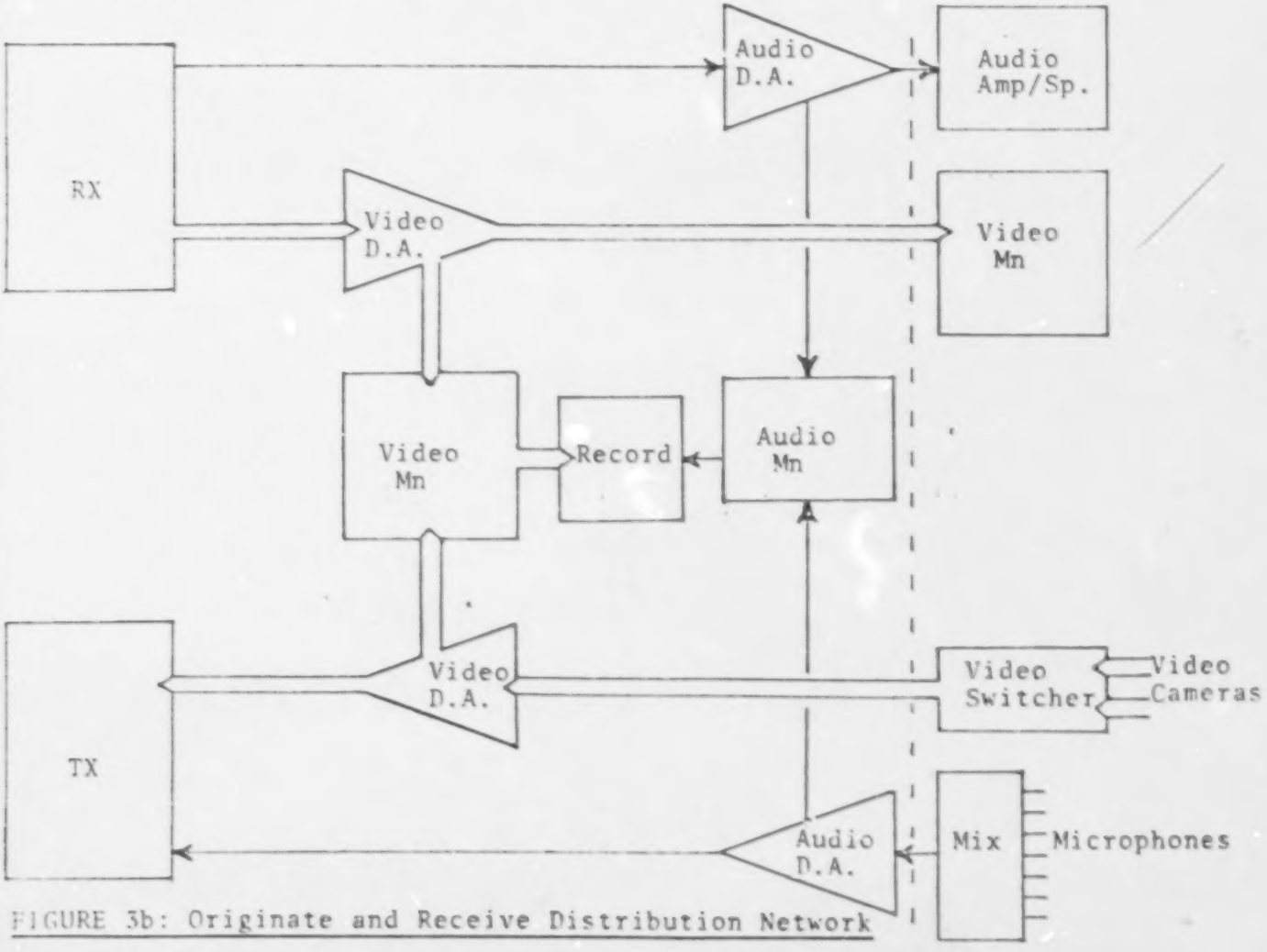

FIGURE 3b: Originate and Receive Distribution Network

a) 24 student receive-only classroom, 2 large TV monitors, 4 microphones on stands.

Items	Cost		
	Number of Classrooms		
Capital Costs	1	2	3
Control Centre			
Video Monitor	250	250	250
Audio Mix/Monitor	150	150	150
Video Dist. Amp.	250	500	750
Audio Dist. Amp.	150	300	450
Console	50	100	100
Cabling/Connection	200	300	400
Installation	400	600	800
	1450	2200	2900
Classroom			
(2) large monitors	800	1600	2400
(4) mics./push to talk	250	500	750
Audio Mixer	150	300	450
Monitor/Mic. Stands	200	400	600
Cabling/Connections	50	100	150
Installation	200	400	600
	1650	3300	4950
TOTAL	3100	5500	7850

a) Continued.

Items	Cost		
Annual Fixed Operating Costs	Number of Classrooms 1	2	3
Personnel	600	900	1200
Supplies and Services	200	300	400
TOTAL	800	1200	1600
Per-Course Operating Costs (receive or transmit, 1 term)	300		
Per-Course Academic Costs (receive, 1 term)	1500		
Per-Course Academic Costs (originate, 1 term)	-		

b) 24 student receive-only classroom, 2 large TV monitors and one small monitor for each pair of students, one microphone with each monitor.

Items	Cost		
	Number of Classrooms		
Capital Costs	1	2	3
Control Centre			
Video Monitor	250	250	250
Audio Mic./Monitor	150	150	150
Video Dist. Amp.	250	500	750
Audio Dist. Amp.	150	300	450
Console	50	100	100
Cabling/Connections	200	300	400
Installation	400	600	800
	1,450	2,200	2,900
Classroom			
(2) large Monitors	800	1,600	2,400
(12) small Monitors	2,400	4,800	7,200
(12) mics/Push to Talk	700	1,400	2,100
Audio Mixer	150	300	450
Monitor/Mic. Stands	400	800	1,200
Cabling/Connections	150	300	450
Installation	300	600	900
	4,900	9,800	14,700
TOTAL	6,350	12,000	17,600

b) Continued

Items	Cost		
Annual Fixed Operating Costs	Number of Classrooms 1	2	3
Personnel	800	1200	1600
Supplies and Services	400	600	800
TOTAL	1,200	1,800	2,400
Per-Course Operating Costs (receive or transmit, 1 term)	300		
Per-Course Academic Costs (receive, 1 term)	1,500		
Per-Course Academic Costs (originate, 1 term)	-		

c) 120 student receive-only lecture theatre, 5 large TV monitors, 24 microphones.

Items	Cost		
	Number of Classrooms		
Capital Costs	1	2	3
Control Centre			
Video Monitor	250	250	250
Audio Mic./Monitor	150	150	150
Video Dist. Amp.	250	500	750
Audio Dist. Amp.	150	300	450
Console	50	100	100
Cabling.Connections	200	300	400
Installation	400	600	800
	1,450	2,200	2,900
Classroom			
(5) large Monitors	2,000	4,000	6,000
(24) mics./Push to Talk	1,300	2,500	3,700
Audio Mixer	150	300	450
Monitor/Mic. Stands	600	1,200	1,800
Cabling/Connections	150	300	450
Installation	300	600	900
	4,500	8,900	13,300
TOTAL	5,950	11,100	16,200

c) Continued

Items	Cost		
Annual Fixed Operating Costs	Number of Classrooms 1	2	3
Personnel	700	1,100	1,500
Supplies and Services	300	450	600
TOTAL	1,000	1,550	2,100
Per-Course Operating Costs (receive or transmit, 1 term)	300		
Per-Course Academic Costs (receive, 1 term)	1,500		
Per-Course Academic Costs (originate, 1 term)	-		

d) 24 student originate and receive classroom, 2 large TV monitors, one fixed overhead camera, one fixed horizontal camera at the back of the room, camera switching only, 1 lecture microphone, 4 student microphones.

Items	Cost		
	Number of Classrooms		
Capital Costs	1	2	3
Control Centre			
(2) Video Monitors	500	500	500
Audio Mic./Monitor	200	200	200
(2) Vide Dist. Amps.	500	1,000	1,500
Audio Dist. Amp.	150	300	450
Waveform Monitor	800	800	800
Console	100	100	100
Cabling/Connections	250	400	550
Installation	500	700	900
	3,000	4,000	5,000
Classroom			
(2) Cameras/Lens	1,500	3,000	4,500
Switcher	500	1,000	1,500
Small monitor	250	500	750
(5) mics./Push to Talk	300	600	900
Monitor/Mic. Stands	200	400	600
Camera Mounts/Console	600	1,200	1,800
Cabling/Connections	250	500	750
Installation	400	800	1,200
	4,000	8,000	12,000
TOTAL	7,000	12,000	17,000

d) Continued

Items	Cost		
Annual Fixed Operating Costs	Number of Classrooms 1	2	3
Personnel	1,200	1,600	2,000
Supplies and Services	600	900	1,200
TOTAL	1,800	2,500	3,200
Per-Course Operating Costs (receive or transmit, 1 term)	300		
Per-Course Academic Costs (receive, 1 term)	1,500		
Per-Course Academic Costs (originate, 1 term)	3,000		

e) 24 student originate and receive classroom, 2 large TV monitors, one small monitor for each pair of students, one fixed overhead camera, one remote controlled camera, control: switching, fades and splits, 1 lecturer microphone, 12 student microphones.

Items	Cost		
	Number of Classrooms		
Capital Costs	1	2	3
Control Centre			
(4) Video Monitors	1,000	2,000	3,000
Audio Mic./Monitor	200	400	600
(4) Video Dist. Amp.	1,000	2,000	3,000
(2) Audio Dist. Amp.	300	600	900
Video Switcher	1,200	2,400	3,600
Video Recorder	3,500	6,000	8,500
Sync. Generator	600	600	600
Waveform Monitor	800	800	800
Console	200	300	400
Cabling/Connections	400	600	800
Remote Control	400	800	1,200
Installation	800	1,200	1,600
	10,400	17,700	25,000
Classroom			
(2) Cameras/Lens	2,000	4,000	6,000
large monitors	800	1,600	2,400
(13) Mics./Push to Talk	750	1,500	2,250
(14) small Monitors	2,800	5,600	8,400
Monitor/Mic. Stands	400	800	1,200
Camera Mounts/Console	600	1,200	1,800
Cabling/Connections	350	700	1,050
Installation	500	1,000	1,500
	8,200	16,400	24,600
TOTAL	18,600	34,100	49,600

e) Continued

Items	Cost		
Annual Fixed Operating Costs	Number of Classrooms 1	2	3
Personnel	2,000	3,000	4,000
Supplies and Services	1,000	1,800	2,600
TOTAL	3,000	4,800	6,600
Per-Course Operating Costs (receive or transmit, 1 term)	300		
Per-Course Academic Costs (receive, 1 term)	1,500		
Per-Course Academic Costs (originate, 1 term)	3,000		

f) 120 student originate and receive classroom, 5 large TV monitors, one fixed overhead camera, one remote controlled camera, control: switching, fades and splits, 1 lecturer's microphone, 24 student microphones.

Items	Cost		
	Number of Classrooms		
Capital Costs	1	2	3
Control Centre			
(4) Video Monitors	1,000	2,000	3,000
Audio Mic./Monitor	200	400	600
(4) Video Dist. Amp.	1,000	2,000	3,000
(2) Audio Dist. Amp.	300	600	900
Video Switcher	1,200	2,400	3,600
Video Recorder	3,500	6,000	8,500
Sync. Generator	600	600	600
Waveform Monitor	800	800	800
Equit. Console	200	300	400
Cabling/Connections	600	900	1,200
Remote Controls	400	800	1,200
Installation	800	1,200	1,600
	10,600	18,000	25,400
Classroom			
(2) Cameras/Lens	2,000	4,000	6,000
(5) large Monitors	2,000	4,000	6,000
(2) small Monitors	500	1,000	1,500
(25) Mics./Push to Talk	1,500	3,000	4,500
Audio Mixer	200	400	600
Monitor/Mic. Stands	600	1,200	1,800
Camera Mounts/Console	600	1,200	1,800
Cabling Connections	300	600	900
Installation	500	1,000	1,500
	8,200	16,400	24,600
TOTAL	18,800	34,400	50,000

Items	Cost		
Annual Fixed Operating Costs	Number of Classrooms 1	2	3
Personnel	1,800	2,700	3,600
Supplies and Services	800	1,400	2,000
TOTAL	2,600	4,100	5,600
Per-Course Operating Costs (receive or transmit, 1 term)	300		
Per-Course Academic Costs (receive, 1 term)	1,500		
Per-Course Academic Costs (originate, 1 term)	3,000		

4.3 Teaching System Costs

In addition to the communication transmission costs, the annual write-off of capital expenditures, technical operating costs, and the course operating costs, there are some additional expenses associated with the coordination of the network and the courses.

One component of this depends directly on the number of courses: at least a one-half hour coordination session per week is required on the system for the lecturer and tutors in each course to discuss problems. The main cost associated with this will be taken to be transmission expenses.

Clearly, some general coordination of the teaching network is requisite. While this will depend to some extent on the size of the network, much of the cost is fixed. Assuming a system director and a secretary, with allowances for travel and office expenses, and a relatively low overhead location at a university, this is estimated to cost $100,000 per year. This would probably allow for a "users conference" each year.

4.4 Basic Academic Costs

In order to justify some of the academic costs used earlier, and to place the cost of this system in context, it is appropriate to review the general costs of university courses.

This will be based on Carleton University which is largely oriented towards general education, and so the estimates may be somewhat low by comparison to institutions with a higher proportion of professional and graduate programs.

The average salary of a professor is some $24,000 per year. His duties involve teaching, research and general departmental and university administration. A "three course equivalent" teaching load is the norm (this involves compensation for laboratory-based instruction, special responsibilities, etc.). An alternative approach to staffing a term course is the employment of a sessional lecturer at a nominal rate of $1,500. Based on this rate $9,000 or about 40%, of a professor's salary can be attributed directly to teaching. Consequently, taking a direct teaching cost of $1,500 per term course is reasonable.

It may seem in the light of these considerations, that there is little difference between the local personnel costs of a course given on the television network and one given locally without the network. However, this is true only if a suitable sessional lecturer is available to present the course, or if the required expertise exists on campus and is available for the course. If not, then the comparative costing is very different. Based on the academic salary of $24,000 and the 3

course load, the cost of a term course teacher can be taken to be $4,000 if a new professor must be hired. In yet another comparison where a 200% overhead* is assumed on the professional salary this figure rises to $12,000.

These comparisons assume that a new lecturer is needed for the teaching of other courses. If, as sometimes has happened, the new professor is hired to teach a particular course and then fills up his teaching schedule by creating more new courses, then 50% or even 100% of this cost to the institution can be attributed to a single course.

As a result, comparative costs are very dependent on the particular circumstances which prevail. In the best circumstances a term course could cost, as a marginal budget item, only $2,250 for a sessional lecturer and a teaching assistant. At the other extreme, the total cost for that course could be as much as $72,000 if a new lecturer were hired for that purpose, and all overheads were attributed to the new position.

Yet another comparison can be made from the Carleton figures. In 1975, 8448 graduate and undergraduate students were

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* In 1974-75 Carleton's gross income (formula income, tuition fees, special grants, research, text and debenture grants, etc.) was about $40,000,000, and this was almost exactly balanced by expenditures. This amounted to overall expenditures of over $65,000 per full-time equivalent faculty member. Increasing this 10% for inflation yields a current overhead figure of 200% on each $24,000 salary.

registered and may be assumed to have taken the equivalent of five courses each. 6927 part-time students may be assumed to have taken one each, and there were 5670 undergraduate student courses in the summer school along with 806 graduate students counted at 2.5 courses each. The grand total, when divided into that year's overall budget, gives $350 per student per term course. Thus a typical one-term course with twenty students cost $7,000 overall.

APPENDIX B

INFRASTRUCTURE COSTS FOR PETS NETWORK

1. INTRODUCTION

In order to render the investigation as realistic as possible this network has been costed in terms of a specific example. We have designed an imaginary educational telephone network serving the province of Quebec. We believe that the figures and costs given can be applied, mutatis mutandis, to networks serving other regions of the country.

2. MODEL

To lend realism to our investigation we have used as a starting model to Wisconsin Educational Telephone Network (WETN). The success of this network, which is used by some 30,000 people per year, suggests that a network designed on the same principles and respecting the same constraints would be efficient and workable. We are most grateful to Dr Lorne Parker, director of the Wisconsin ETN, for his interest in this study and for the information he has supplied.

3. THE NETWORK

We have conceived a network with 197 stations, 195 in the province of Quebec and 2 in Ottawa. These stations are so placed that, in our estimate, 98% of the population of Quebec would be within 25 miles of a station. The network extends from the US border to the extreme north of the province and includes 6 communities north of the 58th parallel.

4. COSTING THE NETWORK

Costs will be examined under three headings; station costs, transmission costs and control costs.

4.1 Station costs

4.1.1 Rooms

We are assuming a network organised under the auspices of a public body. Stations will be located in rooms made available by government departments, educational institutions and communities at no charge. Provision of a suitable room may be regarded as a membership fee for joining the network. Since this will not always be possible a sum of $50,000 p.a. will be set aside in the control budget (see below) to cover those cases where a community cannot provide a room.

4.1.2 Station personnel

Personnel costs will vary with the complexity of the station equipment and will be considered with this item. In the simplest case of an audio network all that is required is a caretaker to unlock the station room at the appropriate times and verify that one item of equipment is plugged in. This cost, like the room itself, would usually be borne by the participating community. Naturally, as equipment of increasing complexity is added to the station local surveillance will increase in cost.

4.1.3 Station equipment

4.1.3.1 Case A: Audio only

In this case stations are equipped with the Darome Educom Portable conference unit which has proved effective and reliable in Wisconsin. 187 sites would be equipped with the standard 4 microphone version whereas at 10 stations, where larger attendance is expected, a four channel mike mixer and auxiliary sound column is added.

Installation costs (up to 5 telephone jacks par station: channel 1) per site		$ 50.
Conference unit:		
187 sites: 1 Darome Educom (inc. 4 mikes) U.S. price $1100 - per site		1,300.
10 sites: Darome Educom		1,300.
4 channel mike mixer		550.
Auxiliarly sound column		80.
		$ 1,930.

Total installation and equipment (187 x $1350) + (10 x $1,980)	$272,250.
Maintenance	
10 extra Educom units	13,000.
	$ 13,000.
TOTAL EQUIPMENT: CASE A	$285,250.
Average cost per station $1,448.	

4.1.3.2 Case B: Addition of graphics capability

Possible equipment: Talos Telenote @ $2,100 per unit
Electronic Blackboard @ $2,500 per unit

Installation (up to 5 telephone jacks per station channel 2)	$ 50.
Graphics unit 197 sites	2,500.
Total installation and equipment (197 x $2,550)	502,350.
Maintenance	
10 extra graphics units	25,000.
TOTAL ADDITIONAL EQUIPMENT: CASE B	$527,350.
Additional cost per station $2,677.	

4.1.3.3 Case C: Addition of microfiche projector

Microfiche projector ($1,000) 197 sites	$197,000
Maintenance	
11 extra projectors	11,000
TOTAL ADDITIONAL COST EQUIPMENT: CASE C	$208,000.
Additionnal cost per station: $1,056.	

4.1.3.4 Case D: Addition of slow telecopier

Xerox telecopier $1,500) (to operate on channel 2)	197 sites	$295,500.
Maintenance 10 extra telecopiers		15,000.
TOTAL ADDITIONAL COST EQUIPMENT: CASE D		$310,500.
Addition cost per station $1,576.		

4.1.3.5 Case E: Addition of rapid telecopier

a) Buying: Rapifax copier ($12,000)	197 sites	$2,364,000.
Maintenance (outside urban centres): 0. per month per site		
197 sites yearly		189,120.
b) Renting: Rapifax copier $320. per month	197 sites	
197 sites yearly		756,480.

4.1.3.6 Case F: Addition of slow scan TV

Black and White ($17,000.)	197 sites	$3,349.000.
Colour ($40,000.)	197 sites	7,880.000.
Maintenance ? ? ?		

4.2 Transmission costs

4.2.1 Using satellites

Cost of delivering 2 channel audio to 197 sites by 12/14 GHz satellite system was examined in chapter 5. p. 31.

4.2.2 Using terrestrial facilities

For the sake of comparison, we have constructed an imaginary telephone network (page B11) to serve the 197 centres. This network respects the principles laid down by Braun et al. 1) in their description of the Wisconsin network, namely:

1- A fully dedicated 4 wire network.

2- Not more than two bridges between the master bridge and any station.

3- Not more than 20 stations per regional primary bridge.

The system has a master bridge in Quebec and regional primary bridges at Quebec (2), Montreal (2), Chicoutimi, Rimouski, Drummondville, Hull, Val d'Or and Sept-Iles and includes some 44 local bridges. Obviously this is not necessarily the exact configuration that would be adopted were a telephone company to construct the network. Nevertheless we consider that the total line length of the network, 12,462 airline miles, is a realistic figure.

Using this figure, we can calculate the transmission costs for the network by multiplying the number of airline miles by an average line rental cost per mile per month.

4.2.2.1 Line rental costs

Some idea of minimum line rental costs can be obtained by studying circuit rental rates published for the Quebec government telephone network. Rates from Quebec are quoted for some 38 of our 197 sites. Aggregating rates for lines to the 8 regional primaries outside Quebec City gives an average of $1.73 per airline mile (or $2.33 if Telpak terminations and equivalent business service is included).

However, taking only the five most distant cities for which rates are quoted gives a figure of $2.43 per airline mile (or $2,71 if Telpak terminations and equivalent business service is included).

Since the proposed PETS network serves a large number of distant localities a rate of $2,50 per airline mile may be used as a minimum figure.

TOTAL TRANSMISSION COSTS: PER YEAR

1 channel 4 wire dedicated network ($12,462. x 12 $2.50)	$373,860.
2 channel 4 wire dedicated network ($12,462. x 12 x $2.50)	$747,720.

4.3 Control Costs

4.3.1 At hub of network

4.3.1.1 Equipment

The major item is the control console including the functions of:

- programme control
- telephone network control
- sound system control
- network failure detection
- 2 wire/4 wire interface $ 40,000.

Office equipement 10,000.

$ 50,000.

4.3.1.2 Personnel

Technical staff (3 @ $11-17,000.)	$ 42,000.
Technical supervisor	25,000.
Production supervisor	15,000.
Traffic scheduling clerk	10,000.
Programme coordinator	15,000.
Instructional designers (2 @ $16,000.)	32,000.
Secretaries (2 @ $10,000.)	20,000.
Maintenance clerk	12,000.
Network director	30,000.
	$201,000.

4.3.1.3 Space

10,000 square feet @ $10. per year	$100,000.
Office expenses per year	10,000.
	$110,000.

4.3.2 At stations

Control and supervisory costs at stations depend greatly on the complexity of the system. As already stated, a simple audio system with microfiche projector requires only unskilled surveillance which would normally be provided by the institution at which the station is located. Clearly a fully fledged station with slow scan and rapid facsimile equipment would require higher level of supervision and this, as much as the capital cost, argues against the multiplication of such stations. We estimate for station control costs an annual budget of $50,000.

TOTAL CONTROL COSTS:	
Capital investment	$ 50,000.
Annual operating costs	361,000.

5. CONCLUSIONS

The costs given, as well as the present state of slow scan and rapid facsimile transmission, argue against including this equipment at all stations. More realistic networks would be:

1) Audio and microfiche projectors at all sites.

2) Audio, microfiche projectors and graphics capability at all sites.

3) Audio, microfiche projectors, graphics capability and slow telecopier at all sites.

4) Network I including a smaller (e.g. 30 stations) network of type 3.

5) Network I including a smaller network with rapid telecopier and/or slow scan facilities.

Costs for these networks would be as follows.

NETWORK 1:

Investment stations:	Audio	$285,000.
	microfiche	208,000.
Investment control		50,000.
	TOTAL INVESTMENT	$543,250.

Operating costs:	Control	$361,000.
	Transmission	373,860.
	TOTAL OPERATING COST	$734,860.

Operating cost per hour (200 days at 12hr/day): $306.

NETWORK 2:

Investment stations	Audio	$285,250.
	Microfiche	208,000.
	Graphics	527,350.
Investment control		50,000.
	TOTAL INVESTMENT	$1,070,600.
Operating costs	Control	$ 361,000.
	Transmission	747,720.
	TOTAL OPERATING COST	$1,108,720.

Operating cost per hour: $462.

NETWORK 3:

Investment stations	Audio	$ 285,250.
	Microfiche	208,000.
	Graphics	527,350.
	Copier	310,500
Investment control		50,000.
	TOTAL INVESTMENT	$1,381,100.
Operating costs (same as network 2)		$1,108,720.

Operating cost per hour: $462.

NETWORK 4:

Costs of small network
(30 stations, 2,000 airline miles)

Investment costs	Graphics (32)	$ 81,600.
	Telecopier (32)	48,000.
	TOTAL	$864,000.
Operating costs	Transmission	$ 60,000.

Additional operating cost per hour
(200 days at 2 hr/day): $150.

NETWORK 5:

Costs of small investment network

	Slow scan (32B/W)	$544,000.
Operating costs	Rapifax rental (30)	115,200.
	Transmission	60,000.
		$175,200.

Additional operating cost per hour: $438.

ATTACHMENT 1

PETS: Quebec as an example

This network of 197 stations would put > 98% of the population within 25 miles of a station. It has been designed according to the following principles*

- Not more than 2 bridges between the master bridge and any station.
- Not more than 20 stations per regional primary bridge.

* See "ETN: A Technical System" by D. Braun et al. in "The Status of the Telephone in Education", L. Parker, B. Riccomini Eds. University of Wisconsin Extension, 1976.

Mileages are airline miles.

PETS STATIONS QUEBEC

197 stations designed so that > 98% of the population is within 25 miles of a station.

REGIONAL PRIMARY	Number of stations	Total airline miles
Québec A	20	523
Québec B	17	929
Chicoutimi	20	804
Rimouski	20	1311
Drummondville	20	551
Montréal A	20	460
Montréal B	20	318
Hull	20	1130
Val d'Or	20	2670
Sept-Iles	20	3766
	197	12462

REGIONAL PRIMARY CHICOUTIMI

LB	La Malbaie	La Malbaie	1	
	72	St-Siméon	24	
		Baie St-Paul	24	
		Les Escoumins	65	186
LB	Chibougamau	Chibougamau	1	
	220	Chapais	30	251
LB	Alma	Alma	1	
	40	Hébertville	12	
		Desbiens	20	73
LB	St-Félicien	St-Félicien	1	
	72	Roberval	14	
		Normandin	15	
		Dolbeau	20	122
	Chicoutimi		2	
	Chicoutimi Nord		4	
	Jonquière		10	
	Arvida		6	
	Kénogami		8	
	Port Alfred		10	
	Bagotville		12	52
				684
		Q - Chicoutimi		120
				804

REGIONAL PRIMARY RIMOUSKI

LB	Ste-Anne des Monts	Ste-Anne des Monts	1	
	110	Cap Chat	10	
		Mont Louis	42	
		Murdochville	50	213
LB	Gaspé	Gaspé	1	
	250	Grande Vallée	40	
		Rivière au Renard	12	303
LB	Chandler	Chandler	1	
	190	Percé	25	
		Paspébiac	40	256
LB	Carleton	Carleton	1	
	120	New Richmond	15	
		Bonaventure	30	
		Restigouche	35	201
LB	Amqui	Amqui	1	
	55	Sayabec	15	
		Causapscal	15	86
	Rimouski		2	
	Mont Joli		20	
	Matane		60	82
				1141
		Q - Rimouski		170
				1311

REGIONAL PRIMARY QUEBEC A

LB	Rivière-du-Loup	Rivière-du-Loup	1	
	100	Trois-Pistoles	25	
		Cabano	30	
		Dégelis	50	
		St-Pascal	25	231
LB	Montmagny	Montmagny	1	
	40	St-Jean Port Joli	25	
		La Pocatière	40	106
LB	St-Joseph de Beauce	St-Joseph	1	
	40	Ste-Marie	10	
		St-Georges	20	
		Lac Etchemin	20	91
	Donnacona		25	
	St-Raymond		25	
	Ste-Anne-de-Beaupré		20	
	Québec Metro 1		5	
	" " 2		5	
	" " 3		5	
	" " 4		5	
	" " 5		5	95
				523
		Q - Q		0
				523

REGIONAL PRIMARY DRUMMONDVILLE

LB	Victoriaville	Victoriaville	1	
	35	Laurier Station	35	
		Plessisville	15	
		Thetford-Mines	35	
		Disraéli	35	156
LB	Richmond	Richmond	1	
	25	Windsor	10	
		Asbestos	15	51
LB	Sherbrooke	Sherbrooke	1	
	50	East Angus	10	
		Lennoxville	3	
		Coaticook	20	84
LB	Trois-Rivières			
	35	Trois-Rivières	1	
		La Pérade	20	
		Nicolet	5	
		Cap de la Madeleine	3	64
LB	Grand-Mère	Grand-Mère	1	
	60	Shawinigan	5	
		La Tuque	60	126
	Drummondville		1	1
				481
		Q - Drummondville		70
				551

REGIONAL PRIMARY MONTREAL A

LB	Waterloo	Waterloo	1	
	60	Magog	20	
		Granby	10	
		Cowansville	15	106
LB	St-Jean	St-Jean	1	
	25	Iberville	2	
		Chambly	10	
		Farnham	15	
		Sherrington	20	73
LB	Mont St-Hilaire	Mont St-Hilaire	1	
	20	Beloeil	3	
		St-Hyacinthe	10	
		St-Marcel	15	49
LB	Verchères	Verchères	1	
	20	Sorel	25	
		Contrecoeur	10	
		Ste-Julie	10	66
LB	Longueuil	Longueuil	1	
	5	Boucherville	5	
		St-Hubert	5	16
				310
		Q - Montréal		150
				460

REGIONAL PRIMARY MONTREAL B

LB	Valleyfield		Valleyfield	1	
	20		Huntingdon	10	
			Ormstown	10	
			Beauharnois	10	51
LB	Rive-Sud		Châteauguay	5	
	5		Laprairie	5	
			St-Lambert	5	20
LB	Vaudreuil		Vaudreuil	1	
	20		Rigaud	10	
			Dorion	5	36
LB	Ste-Thérèse		Ste-Thérèse	1	
			St-Eustache	5	
			Terrebonne	10	26
	Laval			5	
	Montréal Métro	1		5	
	" "	2		5	
	" "	3		5	
	" "	4		5	
	" "	5		5	
	" "	6		5	35
					168
			Q - Montréal		150
					318

REGIONAL PRIMARY HULL

LB	Ville-Marie	Ville-Marie	1	
	250	Témiscamingue	50	
		N.-D. du Nord	24	325
LB	Hull	Hull	2	
	0	Aylmer	5	
		Ottawa A	5	
		Ottawa B	5	17
LB	Thurso	Thurso	1	
	30	Buckingham	10	
		Montebello	15	
		Lachute	50	106
LB	Mont-Laurier	Mont-Laurier	1	
	90	Maniwaki	25	
		La Macaza	35	151
LB	St-Jovite	St-Jovite	1	
	80	Ste-Agathe	20	
		St-Adèle	30	131
	Fort Coulonge		70	
	Shawville		40	
	Kazabazua		40	150
				880
		Q - Hull		250
				1130

REGIONAL PRIMARY VAL D'OR

LB	Rouyn	Rouyn	1	
	60	Lasarre	45	
		Noranda	2	108
LB	Lebel sur Quevillon	Lebel sur Quev.	1	
	80	Matagami	60	
		Desmaraisville	60	201
	Val d'Or 1			
	Malartic 15			
	Amos 35			
	Barraute 25			
	Senneterre 35			
LB	Radisson	Radisson	1	
	400	Sakami	60	
		Fort George	30	491
LB	Eastmain	Eastmain	0	
	300	Nouveau Comptoir	60	
		Fort Rupert	60	420
LB	Poste de la Baleine	Poste de la Baleine	0	
	500	Inoucdjouac	250	
		Povungnituk	350	1100
				2320
		Q - Val d'Or		350
				2670

REGIONAL PRIMARY SEPT-ILES

LB	Baie Comeau	Baie Comeau	0	
	130	Hauterive	10	
		Ragueneau	20	
		Forestville	60	210
LB	Tête à la Baleine	Tête à la Baleine	0	
	350	Lourdes de Blanc		
		Sablon	120	470
LB	Hâvre St-Pierre	Hâvre St-Pierre	0	
	150	Kégashka	130	280
LB	Wabush	Wabush	0	
	200	Fermont	5	
		Gagnon	100	
		Schefferville	150	455
LB	Fort Chimo	Fort Chimo	0	
	600	Port Nouveau-Québec	120	
		Bellin	160	880
LB	Déception	Déception	0	
	850	Ivujivik	120	970
	Sept-Iles		1	
	Port Cartier		40	
	Port Menier		110	151
				3416
		Q - Sept-Iles		350
				3766

REGIONAL PRIMARY QUEBEC B

LB	Hâvre aux Maisons 500	Hâvre aux Maisons	0	
		Hâvre Aubert	25	
		Grande Entrée	15	540
LB	Joliette 125	Joliette	2	
		Louiseville	30	
		Berthierville	10	
		St-Gabriel	40	
		St-Michel des Saints	50	
		L'Assomption	15	
		Repentigny	25	
		St-Jérôme	35	
		St-Esprit	15	347
	Loretteville		5	
	Charlesbourg		5	
	Valcartier		10	
	Lévis		2	
	St-Laurent		20	42
				929
		Q - Québec		0
				929